Small Systems, Big Targets:

Power Sector Reforms and Renewable Energy in Small Systems

*Rabindra Nepal**

School of Economics and Finance, Massey University

Tooraj Jamasb

Durham University Business School, Durham University

Anupama Sen

Oxford Institute for Energy Studies

Abstract

There is some consensus that the traditional energy-only electricity markets, where prices are based on system marginal cost, cannot function efficiently with both fossil fuels and renewables, resulting in market disruptions and price volatility. Consequently, much effort has been focused on how to integrate these different resources in larger and mature electricity systems such as the use of capacity markets in addition to energy-only markets. This paper argues that the effectiveness of competition is limited by the size of an electricity system and there is a threshold size (and associated characteristics such as tropical locations, lack of access, and the prevalence of remote communities of consumers) below which competition will not produce the expected outcomes. This paper contributes to the policy discourse by discussing the reform of small electricity systems to integrate renewable energy via the means of three case studies: Nicaragua, El Salvador, and Australia's Northern Territory. The paper concludes that electricity reforms and renewables can be complementary in small systems when supported by appropriate instruments and incentives. We draw policy lessons for other small systems that are pursuing a triad of objectives including electricity reform, large-scale renewables development and improving energy access.

Keywords: electricity, reforms, renewables, territories

JEL Classification: D04; L94; Q48; L51

*Corresponding author: Massey Business School, School of Economics and Finance, Massey University, Email: R.N.Nepal@Massey.AC.NZ

1. Introduction

The global energy landscape and operating environment of the electricity supply industry (ESI) are undergoing a slow but certain transformation. The electricity sector is waking up to new disruptions occurring at the grid edge (Arriaga et al., 2017). Distributed energy, clean energy demand and technological progress are reshaping the traditional, centralized fossil fuel-based electricity systems, to accommodate variable renewables and other network-related loads (Sioshansi, 2017). The number of consumers becoming 'prosumers'[1], either through improvements in energy efficiency, or through distributed energy resources, is also on the rise. These changes will become more pronounced as energy storage advances into a viable grid-based resource.

Falling wholesale energy prices at a time of rising generation costs, stagnant energy demand growth and growing penetration of renewable energy and other distributed energy resources are part of the transformation (Sioshansi, 2015). These transformations were not anticipated by policy-makers advocating market-based reforms in the early 1990s. The latter were largely motivated by the breakdown of the traditional economies of scale argument associated with vertical integration of the electricity supply industry, and the potential for competition to lower prices, encouraging innovation in generation and retail supply. "*Competition where feasible, regulation where not*" was the overriding principle of market-based reforms (Newbery, 2002). Electricity sector restructuring, when coupled with effective regulation and competition, was expected to deliver significant consumer benefits when designed and implemented well (Joskow, 2003).

[1] A 'prosumer' is an economic agent such as a household that supplies excess energy produced to the grid (producer) but also consumes electricity from the grid (consumer).

Policy attention of late has also focused on the suitability of electricity market reform carried under the 'standard' or prescriptive approach – the end result of which is market liberalization – for the integration of intermittent renewables. There is a growing concern that traditional energy-only electricity markets where price and investment signals are based on system marginal cost cannot function efficiently with both fossil fuels and renewables. The former have high marginal costs and the latter have zero marginal costs, potentially resulting in market disruptions and price volatility. Consequently, policy has focused on finding new ways to integrate renewables and fossil fuels through adopting competitive solutions (such as the use of capacity markets in addition to energy-only markets) (Sen et al., 2016).

A generic high-level reform of the ESI (the "standard approach" involves steps such as: corporatisation, vertical unbundling (separation) and restructuring of the sector, introducing competition in the wholesale generation, horizontal separation of incumbents to create competition, establishing an independent regulatory authority, and privatization of competitive segments of the ESI (Jamasb et al., 2017). The extent of vertical separation has varied across functional, accounting, legal, or ownership separation. Vertical separation was also expected to prevent cross-subsidization between competitive segments and regulated network businesses, and discriminatory behaviour such as denial of access to networks (Joskow, 1998). However, policymakers and scholars have not adequately addressed the central question of "what are the implications of a small electricity system on the effectiveness of market-oriented reforms?"

This paper argues that the effectiveness of reform and competition is limited by the size of an electricity system – in other words, there is a threshold size (and associated characteristics) under which competition by itself will not produce the expected outcomes, and for which distinct policy solutions are required to resolve the problems of scaling up and integrating renewables. Small and isolated systems have characteristics which imply that the economic rationale underpinning the reform of large electricity systems is not readily applicable to them, as the benefits from increased competition are limited. Yet, this has not deterred policymakers from attempting the "standard approach" to reforms in small systems, recently including, for instance, Australia's Northern Territory electricity market (Nepal and Menezes, 2017). Simultaneously, many countries (or territories) with small systems have ambitious renewable energy targets, and in principle face similar policy problems as "larger" or more conventional electricity systems, although the drivers behind these targets are related to electricity access for remote communities rather than decarbonisation *per se*.

The absence of prior literature on electricity reforms which accounts for the issues of small systems implies limited scope for learning from previous experience from such systems. Yet they account for a small but important number of countries in the Asia Pacific, South East Asia and the Caribbean. These countries are particularly vulnerable to climate change, and their reform objectives have included market restructuring alongside improving access and scaling up renewables (Nepal and Jamasb, 2012a; Nepal and Menezes, 2017).

This study attempts to fill the gap in literature by reviewing policy experience in three small electricity systems: two of these – Nicaragua and El Salvador - have successfully integrated renewables to over 50% of generation within a few years. Based on these countries' experience, we identify a number of practical policy solutions. We propose that a third, Australia's Northern Territory, closely fits the generic case for the adoption of a similar approach, as the Territory has adopted an ambitious renewable energy target in the midst of ongoing power sector reforms. We conclude with policy options for countries or territories which face the problem of reforming electricity markets to integrate renewables, and which fit the characteristics of small electricity systems.

We suggest that electricity sector reforms and renewables can be complementary when supported by appropriate instruments and incentives in small systems. A sophisticated regulatory institutional framework is desirable, but is neither a necessary condition nor a guarantee for successful renewable energy development. Private sector investments can (but not necessarily always) correlate with a high share of renewables.

The remainder of the paper is as follows. Section 2 outlines the characteristics of small electricity systems and sets out the preliminary arguments on why these could adopt renewables integration alongside the 'standard' electricity reform model. Section 3 presents case studies on Nicaragua and El Salvador – two successful cases of electricity market reform and renewables integration in small systems - and Australia's Northern Territory. It documents existing policies and arrangements for renewable energy development in these markets. Section 4 synthesises policy lessons drawn from the case studies, applicable to other small electricity systems globally. Section 5 concludes.

2. The Characteristics of Small Electricity Systems

Several small systems have undertaken the process of restructuring their sectors to introduce greater competition riding on the 'wave' of popularity of electricity market reforms that were initiated and spread worldwide in the 1990s. Examples include countries in Africa, and small economies and territories in the Caribbean and the Pacific (Weisser, 2004). In this section, we discuss the features of small electricity systems and summarize the literature addressing the unsuitability of electricity reforms in the scaling and integration of renewables.

“Small” electricity systems can be defined by a set of distinct characteristics. In absolute terms, the literature defines a small electricity system as one that has an installed electricity capacity of below 1,000 Megawatts (MW) (Besant-Jones, 2006). This is, however, not the sole characteristic. An electricity system can also be considered “smaller” relative to a wider electricity market. This could include a system situated within a country (such as the provincial markets in Australia), or within a wider region (such as individual systems within a transnational network – for instance the countries within Latin America’s SIEPAC network) which accounts for a small proportion of that overall system. The Single Electricity Market (SEM) in Ireland is an example of a smaller and isolated market in the European context (Nepal and Jamasb, 2012b). An important trend including some small power systems globally is the formation of power trade areas with neighbouring countries and are summarised in USAID (2016).

In many small systems, energy demand is often too low (and the demand base is too small) to allow the benefits of greater competition to manifest – for instance, through the lowering of electricity prices. Small electricity systems are also sensitive to the impact of large foreign investors and developers in electricity generation and distribution (Besant-Jones, 2006). The benefits of greater competition in small electricity systems may be lower than the transaction costs involved in fostering competition. Alternatively, the benefits of greater competition in small systems may be lower than the benefits obtained from economies of coordination and scope under vertical integration. The costs of vertical separation may be so large to offset the gains from competition even when it is possible to introduce limited competition in generation and achieve some benefits (Bacon, 1994). Hence, countries with small systems can have intermediate reform options although some degree of vertical separation is likely to improve quality of services and lower costs.

Many small systems are geographically distinctive, and prevalent largely among countries in the tropics with higher energy demand (Central America, the Asia- Pacific and the Caribbean). Given their often maritime locations and vulnerability to the impacts of climate change and oil market volatility, many small systems have adopted ambitious renewable targets. Small systems in the tropics often host remote communities with relatively poor electricity access. Finally, small systems in the tropics generally have other reliable resources of renewables to draw on, such as continuous/more predictable solar, and often hydro, rather than solely relying on imported fossil fuels. As of 2014, there were around 88 small electricity systems in the world measured in terms of installed generation capacities (see Table 1A). These small systems are predominantly located in Africa, the Caribbean and the Pacific.[2] An earlier study by Bacon and Besant-Jones (2001) had estimated that around 100 countries have power systems smaller than 1000 MW.

Given the distinctive characteristics of small electricity systems, market-based reform may have lesser relevance to such systems (Bacon, 1994). The "standard" or prescriptive model of electricity reforms – which is based on moving to liberalised markets with prices set according to system marginal cost – is debated in the literature as being unsuited to the integration and scaling up of renewables (Keay et al., 2013; Sen, 2014; Sen et al, 2016). In order to summarise this debate, in energy-only markets that

[2] Some small island economies also have small electricity systems. However, the implications of reforms in island economies is a body of literature in itself and hence is not the focus of this paper. See, e.g., Niles and Lloyd (2014), Dornan (2015) and Timilsina and Shah (2016).

were originally designed for fossil fuels, where prices are set based on system marginal costs, the incorporation of zero marginal cost renewables can potentially lead to price volatility, as prices would be zero (or very low) during periods when renewables are plentiful (i.e., the sun is shining or the wind is blowing). Conversely, they would need to be very high when renewables are unavailable, in order to incentivise investors to build the backup fossil-fuel generation required to stabilise the system.[3]

3. Cross Country Case Studies

The problems faced by economies with small power systems in market reforms are similar to those faced by larger systems, although with varying intensity (Besant-Jones, 2006). However, small systems have a range of options available to them, without risking market disruption or hindering market design. These can support the development of renewable energy alongside restructuring the sector to operate more efficiently. The size of small electricity systems also limits the disruptive effects of a large-scale integration of renewables. This has been demonstrated for instance in small electricity systems in Central America. In this section, we provide an overview on the status of power sector reforms and renewable energy development in Nicaragua, El Salvador and Australia's Northern Territory using a cross-country case study approach. We describe some specific characteristics to portray the underlying context in which power sector reforms have been implemented in these economies.

[3] This precludes the availability of storage at some point in the future. High prices would be needed for backup generation given the unpredictability of wind or solar energy, as backup generators would not know whether their plants would be dispatched. See Keay et al. (2013) for a thorough exposition.

The use of multi-country case studies is a popular technique to study the process and outcomes of electricity sector reforms in many developing and developed countries (Jamasb et al., 2017). Case studies can examine issues that do not easily lend themselves to rigorous quantitative analysis or that cannot be analysed due to the unavailability of disaggregated data. Further, the relatively sparse number of small systems in existence[4] limits our case selection to some extent, which is largely based on three parameters:

(a) They fit the characteristics of small electricity systems as outlined in Section 2.
(b) They have common objectives in electricity reforms, namely – improving access and harnessing and scaling up their significant renewables potential.
(c) These are countries/territories that presently have (or are aiming to adopt) sophisticated competitive trading arrangements in their wholesale power markets, despite being small in size.

We focus on two countries with smaller systems in Latin America - a continent with substantial experience in electricity market reforms – which have also successfully scaled up renewables. Power sector reform has been widely adopted in Latin America since Chile's pioneering efforts in the 1980s in opening up the sector to private participation and competition (Pollitt, 2004; Millan, 2005) and has experienced some of the largest absolute increases in renewable energy investment among all developing world regions, totalling US$ 16.4 billion (6% of the global total) in 2015 with Chile, Brazil and Mexico recognised within the top 10 largest renewable energy markets globally (IRENA, 2016).[5] Furthermore, Nicaragua has a generation target of attaining

[4] See Table 1A.
[5] This also includes investments in hydropower.

91% of its energy from renewables by 2027, while El Salvador has set technology specific targets for the scaling up of renewables.

Our third case study is Australia's Northern Territory. Recent reforms in the Territory's electricity sector have involved harmonisation of the local institutional framework with the national frameworks of the Australian Energy Regulator (AER) and the Australian Energy Market Commission (AEMC) (NT Government, 2016). Hence, the institutional framework for intraregional market expansion - by interconnecting the Territory to the larger National Electricity Market (NEM) - is already in place, since these markets are also becoming subject to national energy laws and rules. Nicaragua and El Salvador are part of the SIEPAC interconnection- which has substantially benefitted their market reform and renewables integration goals – and the Northern Territory is similarly placed within Australia.

Nicaragua and El Salvador have a tropical climate with pronounced dry and wet seasons as does Australia's Northern Territory. They have installed capacities of 1345.77 MW and 1695.05 MW respectively. Both of these economies have significant potential for solar, geothermal and wind energy (IRENA, 2016).[6] Figure 1 shows that the shares of renewable electricity generation capacity (MW) during 2015 were 29% and 42% in El Salvador and Nicaragua respectively – indeed, investments in renewable energy generation are almost at par with non-renewable energy in Nicaragua. Each of these countries attracted approximately 314 million USD and 857 million USD investments in clean energy between 2011 and 2015.

[6] El Salvador has the highest geothermal energy production in Central America (with 26% of energy generated from geothermal in 2015).

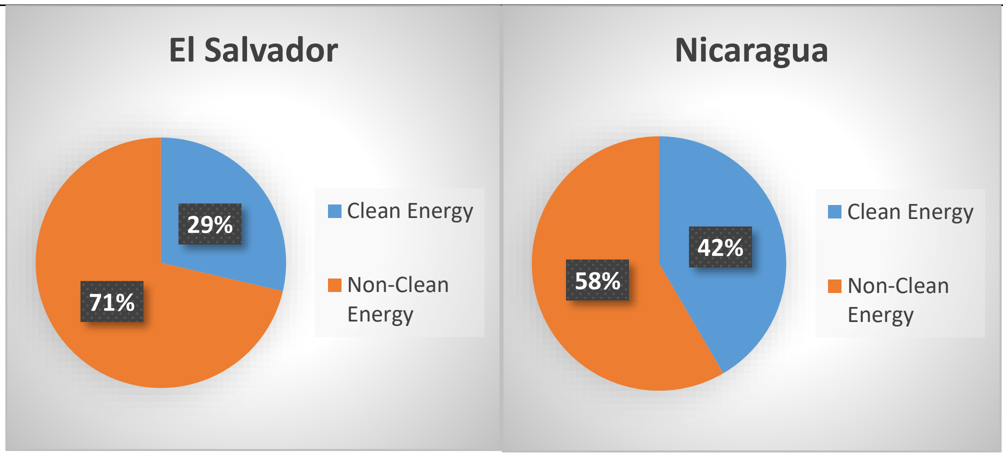

Figure 1: Share of installed generation capacities (MW) in 2015
Source: CLIMATESCOPE (2016)

In El Salvador the addition of renewable capacity aims to diversify the energy mix and reduce oil dependency, given that 43% of electricity generation was oil-based in 2015. Nicaragua, on the other hand, established an interim renewables target of 74% by 2018 and 91% of generation, including hydropower, by 2027, in its November 2013 national plan for electricity expansion. Electricity reforms to move from a vertically integrated monopoly structure to the opening up of generation, transmission, and distribution segments to competition were initiated around the same time in both economies - in 2000 by Nicaragua and in 1997 by El Salvador (Barosso and Perez-Arriaga, 2010). The energy markets of both countries are neither fully vertically integrated nor fully liberalised, perhaps demonstrating the limits of competition.

The electricity system in the Northern Territory, on the other hand, has transitioned from a state-run to a market-based system by undertaking the accounting separation of the previously vertically integrated system. The Territory is looking into competitive market designs of its wholesale and retail sectors. Approximately 99% of grid-supplied electricity in the NT is currently generated by natural gas, with 1% sourced from renewables.

3.1. Electricity Market Reforms in Nicaragua, El Salvador and Northern Territory

Electricity market reforms in Nicaragua were initiated as early as in 1994. Prior to this, all operational and regulatory functions were assigned either explicitly or implicitly to the state-owned monopoly *Instituto Nicaraguense de Energia* (INE). The operational functions of INE were spun off into a new company, *Empresa Nicaraguense de Electricidad* (ENEL) in 1995, whilst regulatory functions stayed with INE. Electricity reform legislation was passed in 1998 which put in place the following elements (World Bank, 2012):

- A wholesale market with multiple generating companies, remunerated in accordance with a spot price determined as system marginal cost of production (audited variable generation costs),
- A contracts market established through the Supply Guarantee Obligations involving generation and distribution companies and large consumers which provides hedging against currency fluctuations in the spot market, and
- A regulated market of end-consumers, served by distribution companies at prices determined by the regulator (INE).

The Nicaraguan electricity sector was also unbundled into a single transmission company (ENATREL) also in charge of system dispatch; ENEL's generation assets were segregated for privatisation, while its distribution assets and functions were unbundled into two new companies and privatised (World Bank, 2012). Nicaragua's thermal (oil-based) and geothermal generation assets were privatised whereas its hydro assets were not.[7] Notably, the government created a separate state entity - *Comision Nacional de Energia* (CNE) - in charge of planning, policy, rural electrification and legal initiatives. The MEM (the Ministry of Energy and Mines) was created as a successor to CNE as a result of a 2007 legislation, with additional functions that were transferred from INE such as licensing and oil and hydrocarbon policies, as well as the approval of regulations and norms in the energy and mines sector (ESMAP, 2011).

In El Salvador, the development of the energy sector was in the hands of the state since the early 1940s. The energy sector underwent reforms that sought to redefine the role of the State in the sector in the 1990’s (National Energy Council of El Salvador, 2016). Reforms started by allowing SIGET (Superintendencia General de Electricidad y Telecommunications) - which has been in operation since 1997 - to be in charge of regulating the industry. It was created as an autonomous body with its own budget and equity. A new regulatory framework created the environment for a more competitive power sector at the wholesale and retail levels. An energy exchange has also been in operation since April 1998. The Salvadorian market has a regulatory framework that enables all participants to freely operate in generation, transmission and distribution activities. The current El Salvador electricity market is comprised of the following structural framework (National Energy Council of El Salvador, 2016):

- A wholesale spot market (MRS) where the MRS price is production cost-based. Hence, the price of energy depends on variable costs associated with fuel costs, and compensation for every MWh of power made available. Moreover, in early 2005, the remuneration of generators at the marginal cost of generation in the

[7] Primarily as it did not attract much private sector interest; also, the hydro storage capacity was limited.

spot market was replaced by a 'pay–as–bid' scheme to account for higher spot prices due to increasing fuel prices (ESMAP, 2011).

- A '*competitively bid*' long term contracts market (CLP) subject to firm capacity availability involving generators and distribution companies under the supervision of SIGET, where the contracts are financially settled (in terms of monetary values than physically (MWh)) and stabilize energy prices for final users.
- A regulated market of end-consumers, served by distribution companies at prices determined by the regulator.

The restructuring led to the unbundling of generation, transmission and distribution activities and to the horizontal division of generation and distribution into several companies. The state-owned generator, CEL, maintained ownership of hydroelectric plants and created ETESAL (the Salvadoran Transmission Company) as a subsidiary company while all other distribution and thermal generation companies were privatized. UT (the Transaction Unit) was also created as a private company in charge of system operations and of the administration of the wholesale electricity market (MEM) (ESMAP, 2011). In 2007, a legislation creating the National Energy Council (CNE), as the highest authority on energy policy and the coordinating body for the different energy sectors was approved. Table 1 captures the normative, regulatory and design aspects of the electricity markets in Nicaragua and El Salvador.

	Nicaragua	El Salvador
Initiation of Reforms	1994	1997
Normative Entity	MEM	CNE
Regulator	INE	SIGET
System Operator	CNDC of ENATREL	UT
Market Operator/Administrator	CNDC	UT
Transmission Company	ENTRESA	ETESAL
Vertical Integration	No	Yes (separate account)
Market Model	Wholesale Competition	Retail Competition *
Generators	12	16
Transmitters	1	1
Distributors	5	5
Traders	0	11
Large Consumers	9	2
Economic dispatch	Cost based	Price bids
Spot market price	Short Run Marginal Cost with no Transmission constraints	Average of prices based on bid prices of dispatched generators with transmission constraints
Spot market	Hourly energy price: marginal cost	Hourly energy price: marginal price
Spot market dispatch	Economic dispatch based on variable costs	Economic dispatch based on prices and transmission capacities
Traded Products	Power (MW) and Energy (MWh)	Power (MW) and Energy (MWh)
Capacity Payment	Yes	Yes **
Long-term contracts ***	Tender (80% of demand)	Negotiated ****
Contracts	Financial	Physical
Limit of Large Consumers	2000 KW	0 KW
Transmission charges: Losses	Transmissions losses pay by demand	Transmission losses paid by generators
Private participation	Generation= more than 70% of installed capacity; Distribution = 100%	Generation = 70% of installed capacity; Distribution= 100%

*Distribution companies operate under regulated rates and quality constraints. However, based on El Salvador´s current regulations, competition is allowed in distribution even within the same geographical area.

** The Long Term Contracts (CLP) ensure a guaranteed income independent of the actual energy production.

*** Distributors in Nicaragua must have contracted, in advance, 80% of their forecasted demand (for power and energy) for the following year and 60% for the subsequent year. In El Salvador, distributors must contract 50% of their forecasted demand (for the first year), with a maximum of 25% for each independent contract.

**** Public tenders are used by distribution companies in Latin American wholesale electricity markets to select the most favourable electricity supply contracts with generation companies. Such processes are regulated and supervised by the regulatory bodies of each country such as SIGET in El Salvador.

Table 1: Electricity Market Features across different Jurisdictions
Source: Based on ESMAP (2011)

A notable difference between EL Salvador and other Latin American markets is that the electricity Law technically authorizes vertical integration in generation, transmission, distribution and supply - while generation, distribution and supply companies are prohibited from owning shares in ETESAL. This arrangement, coupled with the existence of a price -based spot market with retail competition for all consumers (including large consumers), makes the wholesale electricity market in El Salvador unique, as it preserves competition. From the discussions above, it is clear that Nicaragua and El Salvador, while injecting limited competition, have retained regulatory control over some parts of their electricity systems.

Australia's Northern Territory Electricity Market (NTEM) is another example of a reforming smaller market. The NT market is characterised by a small size (around 700 MW of on-grid installed capacity) with scattered networks, many of which serve the low density loads of remotely based indigenous communities, and often exposed to extreme weather conditions. Its location close to the tropics implies that the NT is also endowed with substantial solar energy resources.

The NT market operated as a vertically and horizontally integrated multi-utilities business from the 1980's until 2014 under the Power and Water Corporation (PWC). The Territory embarked on a set of reform measures in 2012 to promote competition and efficiency in the electricity supply industry. These measures also targeted the greater alignment of regulatory arrangements with those operating in Australia's National Electricity Market (NEM)[8], with a view to improving efficiency and outcomes for Territory electricity consumers (NT Government, 2014). The Northern Territory electricity market is unique as it represents a small reforming power system located within the same Australian national border.

Reform measures so far have included the split of the incumbent PWC into three separate state-owned contestable and regulated entities in accounting and legal terms in July, 2014, namely: Territory Generation (the largest electricity producer owning 592 Mega Watts (MW) of installed capacity and contracting an additional 114.5 MW from the Independent Power Producers (IPPS)) under a standard generation licensee; Power and Water (responsible for managing the networks) and Jacana Energy (the energy retailer). Further measures included the transfer of economic regulation of networks to the Australian Energy Regulator (AER); establishment of an organized wholesale market, and reform of the retail sector. The Territory is looking to the NEM as a model even though energy-only markets are debated as being unsuitable for renewable energy integration, as discussed in Section 2 (NT Government, 2016).

The electricity sector in the NT is regulated by the statutory framework instituted in 2000 involving various legislations administered by the Utilities Commission, including the Utilities Commission Act, Electricity Reform Act, and Electricity Networks (Third

[8] The NEM is the Australian wholesale electricity market operating in Queensland, New South Wales, Tasmania, Victoria and South Australia.

Party Access) Act. This statutory framework is primarily responsible for regulation of the electricity sector in the Darwin-Katherine, Alice Springs and Tennant Creek power systems (also referred to as the regulated systems).

Structural reforms in 2012 followed the commencement of the Interim Northern Territory Electricity Market (I-NTEM) in May 2015 (Nepal and Menezes, 2017). The I-NTEM introduced an efficient economic dispatch of generation and basic market operation functions, providing a framework to facilitate the wholesale arrangements of electricity between electricity generators and retailers.

The establishment of a market operator (MO) along with the existing system controller (SC) supports the overall reform initiatives by removing dispatch decisions from the previously vertically integrated entity. Consumers are allowed to purchase electricity from any licensed retailer approved by the Utilities Commission. The market operator is also responsible for the publication of market data including daily market prices and virtual settlement statements to market participants. Figure 2 outlines the stricture of the I-NTEM market. Table 2 details out the underlying features of this market.

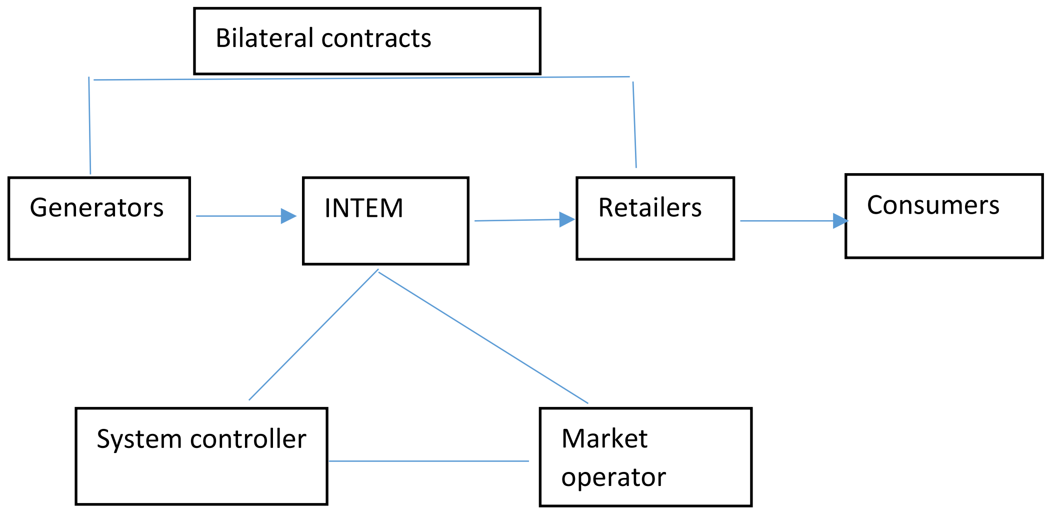

Figure 2: The I-NTEM
Source: Reproduced from Power and Water
(https://www.powerwater.com.au/networks_and_infrastructure/market_operator)

	Northern Territory *
Initiation of Reforms	2000
Normative Entity	NTEM
Regulator	Utilities Commission (under AER)
System Operator	Power and Water
Market Operator/Administrator	Power and Water
Transmission Company	Power and Water
Vertical Integration	Yes (separate account)
Market Model	Retail Competition
Generators	9 **
Transmitters	1
Distributors	1
Traders	6
Large Consumers	-
Economic dispatch	Price bids
Spot market price	Short Run Marginal Cost with Transmission constraints (in the NEM)
Spot market	Half hourly energy price: marginal price
Spot market dispatch	Economic dispatch based on prices and transmission capacities
Traded Products	Energy (MWh)
Capacity Payment	No
Long-term contracts	Negotiated
Contracts	Physical
Limit of Large Consumers	2 GWh
Transmission Charges: Losses	Transmissions losses pay by demand
Private Participation	Generation = 16.26% of installed capacity
* It must be noted that many features of the NTEM are still being discussed since the market is in an interim stage. ** See Utilities Commission (2016).	

Table 2: Electricity Market Features in the NTEM

One of the prominent features of the I-NTEM is bilateral contracting of electricity between retailers and generators. This form of contracting is appealing for countries with small power systems and weak institutional capacity (Bacon and Besant-Jones, 2001). The bilateral contracts provide for competition only at the time of bidding for the right to secure such contracts. They do not allow competition to develop as trade takes place in the market. As such, bilateral trading is the most common successor to a single buyer once the basic requirements for competition in the market are met (Besant-Jones, 2006). Settlement for the contracted power is also carried out bilaterally, and each distributor is financially responsible for its own contracts under bilateral trading.

The Darwin-Katherine interconnected system is the only interconnected system linked by a 132 kV transmission line from Darwin to Katherine representing three quarters of the total Territory Generation Capacity. The power networks are highly scattered (see Figure 1A). More than 5800km of overhead lines, 3000km of underground cable and 40,000 poles connect Territorians to the electricity network (Power and Water, 2017). The Darwin-Katherine, Tennant Creek and Alice Springs networks are not interconnected and are separated by long distances. There are six licensed electricity retailers in the Territory, namely: Power and Water, Jacana Energy, Energy, ERM Power Retail Pty Limited, Rimfire Energy and EDL NGD (NT) Pty Limited (Utilities Commission, 2016). The predominant fuel sources used in the Northern Territory for electricity generation are gas, liquid fuels (such as diesel and heavy fuel oil) and with only a small proportion (one percent) from renewable energy.

The I-NTEM is in a transition stage towards a fuller NTEM (Nepal and Menezes, 2017). Wholesale prices are determined by bilateral contracting and generator dispatch is determined based on the generators offers as there are no financial transactions currently taking place in the I-NTEM. Moreover, the generators utilise the I-NTEM settlement statements to determine the settlement quantities for their bilateral contracting arrangements (NT Government, 2016). The virtual settlement price is an 'energy-only' price and does not contain additional components such as capacity payments to ensure capacity availability. Unlike El Salvador and Nicaragua, the NTEM remains isolated from regional interconnections, but interconnection to the National Electricity Market (NEM) and Wholesale Electricity Market (WEM) in Western Australia is an option.

3.2. Renewable Energy Development in Nicaragua, El Salvador and Northern Territory

Shortly after implementing electricity reforms, Nicaragua began implementing parallel legislation in 2005 to expand the share of renewable energy in electricity in its "*Law for the Promotion of Electricity Generation with Renewable Sources*". It set a non-binding target for 91% of electricity generation from renewables by 2027. The "*National Sustainable Electrification and Renewable Energy Program*" was launched in 2010, which linked the expansion of renewables to rural electrification. A fund was established (the *Energy Investment and Development Fund*) for this purpose, which is funded through tax (VAT) receipts. Renewable energy developers enjoy a full range of tax breaks, including import duty, VAT and income tax exemptions. Electricity distributors must allocate a share to renewable power in their tenders for electricity with biomass, geothermal, hydro, wind and solar being the priority sectors[9]. Electricity generation can also be

[9] INE defines the percentage allocated for renewables in tenders based on the strategic expansion plan originating from the MEM.

contracted through bilateral contracts between generators and distributors and large consumers.

Nicaragua's main policy supporting renewable development is *Law 532*. It mandates renewable energy tenders for the biomass, geothermal, hydro, wind and solar sectors. INE is responsible for defining the percentage allocated for renewables in tenders based on MEM's strategic expansion plan. Generators that do not have contracts with distributors or large consumers may sell their power in the spot market, where they can receive a price determined by near-term supply and demand conditions. The law also offers a variety of tax incentives for renewable projects. In addition to national exemptions, developers receive a reduction on municipal taxes. The government implemented a new pricing benchmark (reference price) for renewable energy technologies in to improve the competitiveness of clean energy sources in the country in 2015.[10] These reference prices apply to biomass, geothermal, hydro, solar and wind projects. Prices vary from \$66-\$80 per MWh (lowest range) for wind projects up to \$103-\$118 per MWh (highest range) for solar plants.

El Salvador's National Energy Policy aims to add technology-specific capacities of 60 MW wind, 90 MW solar PV, 200 MW solar thermal, 60-89 MW geothermal, small hydro (<20 MW) 162.7 MW, 45 MW biomass and 35 MW biogas by 2026 (IRENA, 2015). The country floats technology-specific renewable energy tenders, alongside offering income and import tax exemptions to clean energy projects. Tenders have been introduced to replace bilateral power agreements and encourage renewable energy contracts. The first auction for renewable capacity took place in 2014, and contracted 94MW of solar

[10] The processes involved in determining the reference prices are not publicised clearly. However, we expect the reference prices to cover both *capex* (capital expenditure) and *opex* (operating expenditure) i.e. the *totex* (total expenditure) to make the renewable energy projects viable.

PV capacity to come online in 2016. Capacity was contracted at an average price of $116.2 per MWh under 20-year power purchase agreements. The bidding in a second renewable energy tender opened in February 2016. It aimed to contract up to 150MW of wind and solar PV projects for a maximum duration of 20 years from 2019.

El Salvador grants tax incentives for development of renewable energy sources, including 10 years of import tax exemption to machines and equipment, and income tax breaks for renewable energy projects under decree 462 of 2007. The sale of credits under the UN's Clean Development Mechanism (CDM) for renewable energy projects is additionally not subject to income tax. Furthermore, ETESAL is required to guarantee priority dispatch, as in Nicaragua, to electricity generated from renewable sources. Table 2 enumerates the existing renewable energy policies and instruments in the energy sectors of Nicaragua and El Salvador.

	Nicaragua	**El Salvador**
National Policy	• Renewable Energy Target • Renewable Energy Law/Strategy • Geothermal Law/Programme • Biomass Law/Programme • Biofuels Law/ Programme	• Renewable Energy Target • Solar Power Law/Programme
Fiscal Incentives	• VAT Exemption • Income Tax Exemption • Import/Export Fiscal Benefit • National Exemption of Local Taxes • Other Fiscal Benefits	• Income Tax Exemption • Import/Export Fiscal Benefit

Grid Access	• Preferential Dispatch • Other Grid Benefits such as planning or other fee exemptions	• Preferential Dispatch • Grid Access
Regulatory Instruments	• Auctions • Feed-in- Tariff • Quota • Hybrid	• Auctions • Hybrid • Net Metering
Finance	• Currency hedging • Dedicated Fund • Eligible Fund • Guarantees • Pre-investment support	• Currency hedging • Dedicated Fund • Guarantees • Pre-investment support • Direct Funding
Other	• Renewable Energy in Rural Access Programme • Renewable Energy Cookstove Programme • Special Environmental Regulations	• Renewable Energy in Rural Access Programme • Social Requirements • Special Environmental Regulations

Table 2: Instruments for Renewable Energy Development
Source: Based on IRENA (2015); CLIMATESCOPE (2016)

The electricity market reforms of Nicaragua and El Salvador have taken into consideration the limitations to competition from the small size of their systems in relation to the design of their respective national wholesale markets. Economic dispatch is centralized and based on audited variable costs (except in El Salvador, where it was based on prices, but is poised to change to variable costs) (ESMAP, 2011). Both have established competitive wholesale electricity markets and implemented vertical and horizontal unbundling of generation, transmission and distribution activities to a varying extent. Alongside this, Central America has the largest share of renewables (56%) and one of the world's most diverse mixtures of renewable generation, composed of biomass, geothermal, wind, solar and hydro (Norton Rose Fulbright, 2017).

Both Nicaragua and El Salvador participate in an interconnected power system; namely, the Central American Electrical Interconnection System (SIEPAC). SIEPAC is an interconnection of the power grids of six Central American nations including Panama, Costa Rica, Honduras, Nicaragua, El Salvador and Guatemala. The objective of SIEPAC is to alleviate periodic power shortages in the region, reduce operating costs, optimize the use of renewable energy including hydroelectric power, create a competitive energy market in the region, and attract foreign investment in power generation and transmission systems (ICER, 2015).

The NT labour government has nevertheless adopted an ambitious renewable energy target of 50% by 2030 (Territory Labor, 2015). Hence, there may exist opportunities to align the economic objectives of electricity reforms with climate objectives in the early stages of the NT's reforms. However, uncertainty exists regarding the alignment of electricity reform objectives with climate-related objectives in smaller systems such as the NT, given the ongoing "*industry transformation*". The ability of the electricity industry to resolve the energy policy "trilemma" of security of supply, affordability and sustainability is also being questioned and is attracting increasing support (see, e.g., Keay, 2016 and Pollitt, 2012 for the European context Simshauser, 2014; Nelson et al., 2015 for the Australian context and PJM, 2016 for the US context).

The NT Climate Change Action Policy (2009) established an ambitious goal of 60% reduction in emissions level by 2050 (based on 2007 levels) and of becoming a world leader in providing green energy in remote areas (Climate Council 2014). However, there are currently no formal climate policies, near-term emissions-reduction targets or specific implementation plans to harness RE sources. At the same time, the electricity sector has a key role to play towards decarbonisation.

4. Policy Lessons and Discussion

Several policy options are proposed below for other small electricity systems that are experiencing reforms in the advent of industry transformation. These policy options may also be particularly useful for smaller countries located in geographically complex settings such as the in the Asia-Pacific, South East Asia and the Caribbean where reforms are ongoing alongside policies to decarbonize their economies.

4.1. Increasing Private Participation in the Contestable Segments

Both Nicaragua and El Salvador have significant private sector participation in the contestable segments of their ESI (generation and distribution) unlike the Northern Territory. In both of these markets, the IPP(s) are allowed to sign direct long-term contracts with the retailers as opposed to in the NT. In El Salvador, large consumers can purchase electricity directly from generators. Clean energy investments, including private sector investments, in El Salvador have increased from 14.32 million USD to 328.26 million USD in 2015, while in Nicaragua, investments increased from 423.45 million USD to 1279.93 million USD (CLIMATESCOPE, 2016).[11]

Therefore, a standard first step to electricity market reform in small systems is to allow Independent Power Producers (IPPs) to sell electricity into the wholesale market. Entry can be encouraged in the short-term through favourable (negotiated) power purchase agreements (PPAs) between the IPPS and retailers to create '*competition in the market*'.

[11] The government of Nicaragua announced the decision to invest $10m in renewable energy projects during 2016. In April 2016, South Korea's government confirmed that it would lend $33.3m to the government of Nicaragua for the development of solar projects in 164 rural communities.

The negotiated PPAs can reflect the differences in energy technologies (i.e. promoting renewables over non-renewables). In the longer run with more private participants, contracts could be auctioned or tendered as in Nicaragua and El Salvador to '*compete for the market*'. For instance, the use of renewable energy auctions has led to significant growth in renewable energy capacity in other Central American countries participating in the regional market, including Costa Rica, Guatemala and Panama (IRENA, 2016).

Policy for attracting higher renewable energy investments also needs to focus on improving contract enforcement, thus minimising transaction costs and improving the credibility of the market for private investors. This can be done by streamlining the permitting processes to private investors and standardizing the rules for contracting with IPPs through PPAs.

4.2. Network Arrangements

Electricity from renewable sources is granted priority dispatch guarantee across both Nicaragua and El Salvador (i.e. electricity from eligible renewable energy producers is dispatched first). El Salvador also has guaranteed or regulated grid access for eligible renewable electricity producers while in Nicaragua eligible renewable energy producers are exempted from planning fees. Private participation through IPPs can be improved by changes in market rules, such as ensuring non-discriminatory access to transmission and distribution systems (Woolf and Halpern, 2001). Other small systems such as the NT could embrace these grid access policies. In addition, eligible renewable electricity producers can be exempted or discounted on transmission fees, while also prioritising electricity generated from renewables in case of grid congestion.

The case studies have also highlighted the importance of an independent system operator (ISO) such as in the case of El Salvador. The ISO has a responsibility for controlling the access to and use of the transmission grid by competing generators and retailers, including commercial solar power producers. The ISO model has been globally advocated as wholesale power markets have been introduced and vertically integrated generation monopolies have been horizontally and vertically unbundled (Chawla and Pollitt, 2013). However, both functions of the system controller and market operator are undertaken by the same entity in the NT, which contradicts the ISO model.

4.3. Regional Electricity Integration

Earlier studies on small electricity systems such as Nepal and Jamasb (2012a) and Nepal and Menezes (2017) have highlighted the importance of interconnections and network investments to facilitate the large-scale development of renewable energy. Energy integration and interconnections harness economies of scale and foster competition in smaller and concentrated wholesale markets. Nicaragua and El Salvador countries participate in the Regional Electricity Market (MER) through an interconnected electricity system (SIEPAC) based on a 203 kV transmission network spanning from Guatemala to Panama (1830 km long) serving 35 million customers (see Figure 2A for the geographical coverage of SIEPAC). The interconnected grid is beneficial in terms of attracting investment in generation and transmission, while lowering energy costs. This optimizes the shared use of renewable energy in the region and mitigates vulnerabilities associated with small markets, fuel price volatility and system unreliability (IDB, 2012).

However, a major obstacle to the success of SIEPAC has been the lack of harmonization of regulatory practices and policies of individual member countries.[12]

Electricity market integration and the development of renewable energy requires adequate network infrastructure, considering that renewable energy resources are distributed, and there is a need to extend existing grid networks to resource-rich and resource-poor zones. The lack of adequate network infrastructure and related investments is a barrier to renewable energy deployment. It increases the risks and costs associated with prospective renewable investments. For instance, the lack of interconnection between the NTEM and NEM can be considered a barrier in the development of large-scale renewable energy projects in the NT. However, the harmonization of regulatory frameworks at the start is necessary to facilitate energy integration across small electricity systems in the longer run, as the market expands.

4.4. Policies, Incentives and Support Mechanisms

Central American governments are aware of the importance of renewable energy as a means to reduce their dependence on fossil fuels, evident from their advocacy of clean energy policies. The ambitious renewable energy targets as in Nicaragua and El Salvador reflects strong political will. Both countries have concrete policy mechanisms in place for advancing renewables such as tax incentives (in reducing costs, stimulating investment and increasing the competitive advantage of renewable energy sources). The use of tendering has been successful in scaling up renewable generation. Newer regulatory mechanisms such as feed-in-tariffs exist in Nicaragua while El Salvador has

[12] See IRENA (2015).

introduced net-metering.[13] El Salvador also has adopted a specific national policy through its "Solar Power Law/Programme" programme to support solar energy.

Both El Salvador and Nicaragua have recognized the importance of the investment climate and of stable financing in supporting renewable energy development. Policies are in place to hedge against currency volatility (usually denominating policy benefits in USD) to encourage foreign investments. Both countries have dedicated public funding, such as direct public investment to exclusively finance eligible renewable energy projects. Support is also provided for feasibility studies, resource mapping and other pre-investment activities. Similar policies could be adopted across other small electricity systems globally to meet renewable energy targets.

4.5. Opportunities for Accelerating Rural Electrification

Renewable energy provides opportunities for electrifying rural homes since the technologies make best use of the local available resources. For instance, in 2014, Nicaragua had one of the lowest electrification rates of around 67%, among all Latin American countries in 1990. However, by 2014, the national electrification rate had increased to 82% (World Bank, 2017). The average retail electricity price is still high as compared to other countries ($0.21/kWh in 2014) (Norton Rose Fulbright, 2017). The development of renewable energy is an attractive option in these countries to expand electricity access.

[13] Feed-in tariffs (FITs) and net metering are designed to accelerate innovation and investments in renewable energy sources by allowing energy producers to be compensated for the energy they feed into the grid.

Both Nicaragua and El Salvador have advocated a rural energy access programme that uses or seeks to promote renewable energy. Special environmental regulations are also provided for eligible renewable energy projects in rural areas. Nicaragua has also adopted a programme to specifically promote solar or sustainable bioenergy cook stoves. Other small systems like the NT can integrate these policies into the renewable energy development programme, displacing diesel consumption of diesel among remote (and indigenous) communities.

5. Conclusions

This paper reviewed the experience of electricity reform in small systems alongside the development of renewable energy. We examined the experiences of Nicaragua and El Salvador, and applied these to Australia's Northern Territory system, which is undergoing reforms and poised for an "industry transformation". Both El Salvador and Nicaragua liberalised their electricity markets, unbundled their vertically integrated utilities, and opened generation, transmission, and distribution to competition and private sector. Reforms in the Northern Territory are ongoing. Contrary to the debate over the suitability of the standard reform model in renewable energy integration, these countries are continuing to expand renewable energy despite the range of fossil fuel (often subsidised) options in the markets.

The case studies have underscored that electricity sector reforms and renewables can be complementary when supported by appropriate instruments and incentives in small electricity systems. The economic theory of market failures suggests that goods and service with positive externalities, such as renewable energy, are always under-produced when left to the market due to free-riding. However, market-based interventions in the form of incentives and instruments can create a level playing field for both renewable and non-renewable technologies to compete and co-exist in small electricity systems as well, something which has been advocated by earlier studies on other world regions.

National policies with renewable energy targets and renewable-technology specific law; fiscal incentives through tax exemptions and support for the export and import of renewable energy/equipment; network arrangements such as non-discriminatory grid access and preferential grid dispatch; regulatory instruments such as capacity payments and net metering, and financing arrangements to attract private investments (both domestic and foreign) can help foster renewable energy development across small electricity systems. The role of private sector participation in generation and retail markets, interconnections, and the opportunity to align renewable energy development with expanding energy access in remote regions and communities are important in expanding renewable energy use in small systems.

Future research should focus on the capability of network infrastructure to support the high penetration of renewables and other network related loads, such as grid-based energy storage and plug-in vehicles, in the midst of ongoing industry transformation across small systems. The role of smart grids and smart network regulation in facilitating large-scale penetration of renewable into the grid is also a future area of research involving small electricity systems.

References

Arriaga, I.P., Jenkins, J.D., Battle, C., 2017. A Regulatory Framework for an Evolving Electricity Sector: Highlights of the MIT Utility of the Future Study, Economics of Energy and Environmental Policy, Vol. 6(1), 71-92.

Bacon, R., 1994. Restructuring the Power Sector: The Case of Small Systems, Viewpoint No. 10, June, The World Bank, Washington, DC.

Bacon R. and Besant-Jones, J., 2001. Global Electric Power Reform, Privatization, and Liberalization of the Electric Power Industry in Developing Countries, Annual Review of the Energy and the Environment, Vol. 26, 331-359.

Barroso, B.C. and Perez-Arriaga, I., 2010. The Changing Role of the State in the Expansion of Electricity Supply in Latin America, Energy Policy, Vol. 38, 7152-7160.

Besant-Jones, J.E., 2006. Reforming Power Markets in Developing Countries: What Have We Learned? Energy and Mining Sector Board Discussion Paper No. 19, September, The World Bank Group, Washington, DC.

Chawla, M. and Pollitt, M.G., 2013. Global Trends in Electricity Transmission System Operation: Where Does the Future Lie? The Electricity Journal, Vol. 26 (5), 65-71.

CLIMATESCOPE, 2016. Country Level Insights.
Available at: http://global-climatescope.org/en/

Climate Council, 2014. The Australian Renewable Energy Race: Which States are Winning or Losing? Australia.

Dornan, M., 2015. Renewable Energy Development in Small Island Developing States of the Pacific, Resources, Vol. 4(3), 490-506.

ESMAP, 2011. Regional Power Integration: Structural and Regulatory Challenges, Report No. 58934- LAC, Energy Sector Management Assistance Program, The World Bank, Washington, DC.

Jamasb, T., Nepal, R. and Timilsina, G., 2017. A Quarter Century Effort Yet to Come of Age: A Survey of Electricity Reform in Developing Countries, The Energy Journal, Vol. 38 (3), 195–234.

Keay, M., 2016. Electricity Markets Are Broken – Can They Be Fixed? OIES Paper – EL 17, The Oxford Institute for Energy Studies, University of Oxford.

ICER, 2015. Benefits of Successful Market Integration, The International Confederation of Energy Regulators, Slovenia.

IDB, 2012. IDP Ramps Up Financing for Green Projects in Latin America and the Caribbean, Available at: http://www.iadb.org/en/news/webstories/2012-03-16/financing-for-renewable-energy-in-latin-america,9861.html

IRENA, 2015. Renewable Energy in Latin America 2015: An Overview of Policies, International Renewable Energy Agency, IRENA, Abu Dhabi.

IRENA, 2016. Renewable Energy Market Analysis: Latin America, International Renewable Energy Agency, IRENA, Abu Dhabi.

Jamasb, T., Nepal, R. and Timilsina, G., 2017. A Quarter Century Effort Yet to Come of Age: A Survey of Electricity Sector Reform in Developing Countries, The Energy Journal, Vol. 38 (3), 195-234.

Joskow, P.L., 1998. Electricity Sectors in Transition, The Energy Journal, Vol. 19(2), 25-52.

Joskow, P.L., 2003. Electricity Sector Restructuring and Competition: Lessons Learned, Latin American Journal of Economics, Vol. 40(121), 548-558.

Keay, M., Rhys, J., and Robinson, D., 2013. Decarbonization of the electricity industry – is there still a place for markets?, OIES Working Paper EL9, Oxford Institute for Energy Studies, November.

Millan, J., 2005. Power Sector reform in Latin America: Accomplishments, Failures and Challenges, Economic and Political Weekly, Vol. 40(50), 5291-5301.

National Energy Council of El Salvador, 2016. Electricity Sector of El Salvador, Available at: http://www.cne.gob.sv/index.php?option=com_phocadownload&view=category&download=828:electricity-sector-of-el-salvador&id=72:2015-09-11-16-49-40&Itemid=63.

Nelson, T., Reid, C. and McNeill, J., 2015. Energy-Only Markets and Renewable Energy Targets: Complimentary Policy or Policy Collusion? Economic Analysis and Policy, Vol. 46, 25-42.

Nepal, R. and Jamasb, T., 2012a. Reforming Small Electricity Systems Under Political Instability: The Case of Nepal, Energy Policy, Vol. 40 (C), 242-251.

Nepal, R. and Jamasb, T., 2012b. Interconnections and Market Integration in the Irish Single Electricity Market, Energy Policy, Vol. 51 (C), 425-434.

Nepal and Foster, 2016. Testing for Market Integration in the Australian National Electricity Market, The Energy Journal, Vol. 37(4), 215-238.

Nepal, R. and Menezes, F., 2017. Regulatory Reforms in Small Energy Systems: Experience from Australia's Northern Territory Electricity Market, Economic Papers, The Economic Society of Australia, forthcoming.

Newbery, D., 2002. Problems of Liberalising the Electricity Industry, European Economic Review, Vol. 46(4-5), 919-927.

Niles, K. and Lloyd, B., 2014. Using Power Sector Reform as an Opportunity to Increase the Uptake of Renewable Energy in the Power Sector: Responding to Peak Oil and Climate Change in Caribbean and Pacific Small Island Developing States, between 1970-2010, Natural Resources Forum, Vol. 38 (1), 14-26.

Norton Rose Fulbright, 2017. Renewable Energy in Latin America, LLP 3887, February, UK.

NT Climate Change Action Policy, 2009. Territory Climate Change, Northern Territory Government, Available at:
http://www.savanna.org.au/nailsma/forum/downloads/Climate-change-policy-NTG.pdf

NT Government, 2014. Northern Territory Electricity Market Reform, Information Paper, Department of Treasury and Finance, Northern Territory Government, Australia.

NT Government (2016). Strategy for Northern Territory Utilities, Department of Treasury and Finance, Northern Territory Government.

Pollitt, M., 2004. Electricity Reform in Chile: Lessons for Developing Countries, Competition and Regulation in Network Industries, Vol. 5(3), 221-263.

Pollitt, M., 2012. The Role of Policy in Energy Transitions: Lessons from Energy Liberalisation Era, Energy Policy, Vol. 50(C), 128-137.

PJM, 2016. Resource Investment in Competitive Markets, PJM Interconnection, Available at: http://www.pjm.com/~/media/768E4AC9442A428AA83776AFDBF48929.ashx

Poudineh, R, Sen, A, and Fattouh, B., 2016. Advancing Renewable Energy in Resource-Rich Economies of the MENA, OIES Paper MEP 15, Oxford Institute for Energy Studies, Oxford.

Power and Water, 2017. Networks and Infrastructure – Market Operator, Available at: https://www.powerwater.com.au/networks_and_infrastructure/market_operator

Sen, A; Nepal, R and Jamasb, T., 2016. Reforming Electricity Reforms? Empirical Evidence from Asian Economies, OIES Paper EL18, Oxford Institute for Energy Studies.

Sen, A., 2014. Divergent Paths to a Common Goal? An Overview of Challenges to Electricity Sector Reform in Developing versus Developed Countries, Oxford Institute for Energy Studies Working Paper EL14.

Simshauser, P., 2014. From First Place to Last: The National Electricity Market's Policy-Induced 'Energy Market Death Spiral', Australian Economic Review, Vol 47(4), 540-562.

Sioshansi, F.P., 2015. Electricity Utility Business Not as Usual, Economic Analysis and Policy, Vol. 48, December, 1-11.

Sioshansi, F.P., 2017. Innovation and Disruption at the Grid's Edge: How Distributed Energy Resources Are Disrupting the Utility Business Model, Elsevier Press, June.

Territory Labor, 2015. Roadmap to Renewables: Labor's Plan to Transition to Renewable Energy in the Northern Territory, 1-6. http://territorylabor.com.au/Portals/territorylabor/RoadmapToRenewables.pdf

Timilsina, G. and Shah, K.U., 2016. Filling the Gaps: Policy Supports and Interventions for Scaling Up Renewable Energy Development in Small Island Developing States, Energy Policy, Vol. 98, 653-662.

UN, 2017. Energy Statistics Database, United Nations Statistics Division, United Nations, Available at: http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AEC

USAID, 2016. Cross-Border Electricity Trade in South Asia: Key Policy, Regulatory Issues/Challenges and the Way Forward. https://sari-energy.org/wp-content/uploads/2016/03/CBET-Policy-Regulatory-Issues-Challenges-and-the-Way-Forward-Background-Paper-Jan-2015.pdf

Utilities Commission, 2016. Utilities Commission Annual Report 2015-2016, Northern Territory Government, Darwin.

Weisser, D., 2004. Power Sector Reform in Small Island Developing States: What Role for Renewable Energy Technologies? Renewable and Sustainable Energy Reviews, Vol. 8, 101-127.

Woolf, F. and Halpern, J., 2001. Integrating Independent Power Producers into Emerging Wholesale Power Markets, Policy Research Working Paper 2703, The World Bank.

World Bank (2012). Nicaragua – Energy Sector Policy Note, Washington D.C.

http://documents.worldbank.org/curated/en/599921468059703194/pdf/696700v20Cat-60y0Note0DM0FINAL02007.pdf

World Bank, 2017. Access to Electricity (% of Population), World Bank Sustainable Energy for all Database.
Available at: http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?page=1

APPENDIX

Asia	System Size (GW)	Caribbean	System Size (GW)	Pacific	System Size (GW)	Africa, Indian Ocean, Mediterranean and South China Sea (AIMS)	System Size (GW)	Europe and others	System size
Mongolia	1	Jamaica	1	Papua New Guinea	0.9	Senegal	1	Montenegro	0.9
Nepal	0.8	Bahamas	0.6	Guam	0.6	Uganda	0.771	Malta	0.62
Brunei	0.78	Suriname	0.4	New Caledonia	0.6	Gabon	0.6	Andorra	0.52
Afghanistan	0.6	Guyana	0.4	Fiji	0.3	Mali	0.6	Moldova	0.5
Macau	0.5	Aruba	0.3	French Polynesia	0.2	Guinea	0.5	Faroe Islands	0.1
West Bank	0.1	Haiti	0.3	Marshall Islands	0.052	Namibia	0.5	Greenland	0.096
Maldives	0.082	American Virgin Islands	0.3	Samoa	0.045	Madagascar	0.5	Gibraltar	0.043
		Barbados	0.2	American Samoa	0.041	Congo	0.5	Saint Pierre and Miquelon	0.028
		Belize	0.2	Solomon Islands	0.037	Malawi	0.4	Falkland Islands	0.01
		Cayman Islands	0.1	Vanuatu	0.030	Mauritania	0.4	Saint Helena	0.008
		Saint Lucia	0.088	Micronesia	0.018	Burkina Faso	0.3		
		Antigua and Barbuda	0.084	Tonga	0.017	South Sudan	0.255		
		Turks and Caicos Islands	0.076	Cook Islands	0.009	Swaziland	0.2		
		Saint Kitts and Nevis	0.0642	Kiribati	0.007	Equatorial Guinea	0.2		
		Grenada	0.050	Tuvalu	0.0051	Bermuda	0.167		
		Saint Vincent and the Grenadines	0.047	Nauru	0.005	Benin	0.163		
		British Virgin Islands	0.044	Niue	0.001	Botswana	0.1		
		Dominica	0.0332			Djibouti	0.1		
		Montserrat	0.005			Cape Verde	0.1		
						Rwanda	0.1		
						Seychelles	0.1		
						Sierra Leone	0.1		
						Niger	0.1		
						Eritrea	0.1		
						Gambia	0.091		
						Togo	0.086		
						Somalia	0.081		
						Lesotho	0.080		
						Burundi	0.066		
						Western Sahara	0.058		
						Central African	0.044		

						Republic			
						Chad	0.041		
						Guinea-Bissau	0.039		
						Liberia	0.027		
						Comoros	0.022		
						Sao Tome and Principe	0.020		

Table 1A: 88 small Electricity Systems around the world with installed capacity of ≤1 GW based on 2014 estimates

Source: Adapted from United Nations Energy Statistics Database, UN (2017)

http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AEC

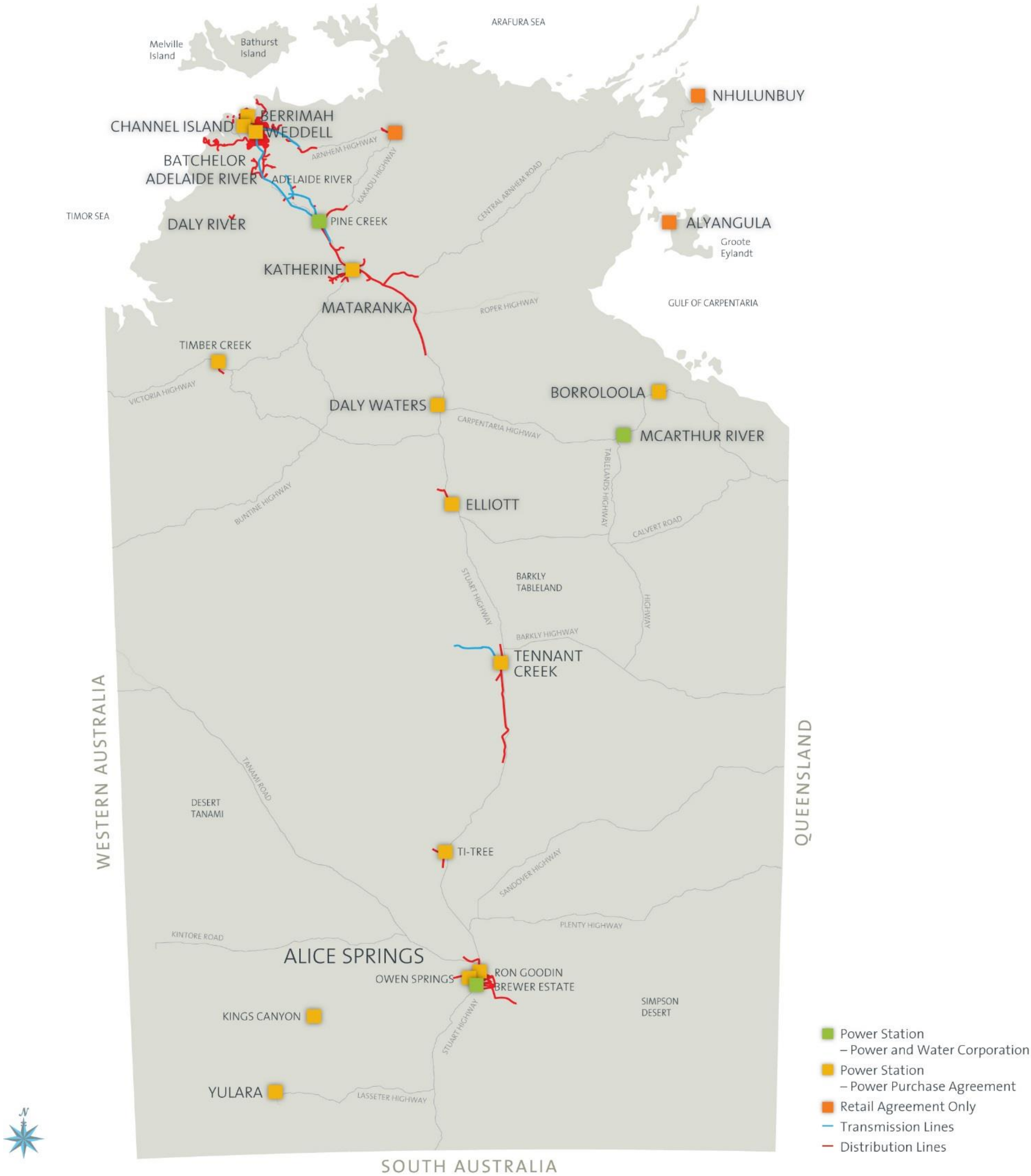

Figure 1A: The I-NTEM

Source: Adapted from Power and Water (2017)

(https://www.powerwater.com.au/networks_and_infrastructure/power_networks)

Figure 2A: The SIEPAC

Source: Reproduced from EPR SIEPAC

(https://www.eprsiepac.com/contenido/)